Symposium* on
Effects of Congestive Heart Failure upon the Circulation
and Metabolism in the Liver;
Hepatic Circulation and Metabolism in Congestive Heart Failure

Chairman: Dr. Tosaku Maeda

1. The Hepatic Circulation in Congestive Heart Failure
2. Hepatic Circulation and Ascites in Congestive Heart Failure
3. Liver Function Tests in Congestive Heart Failure with Special Reference to Enzymatic Activation
4. Discussion

1. The Hepatic Circulation in Congestive Heart Failure†

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In congestive heart failure, that the disturbances in the systemic circulation leading to hepatic dysfunction and histological change is well known by every clinician.

In this paper, the influence of alteration of the systemic circulation in congestive heart failure on the hepatic circulation was studied with the right heart and hepatic venous catheterization.

METHOD

The subjects were 19 patients, 6 patients of them were affected with mitral valve disease, 5 patients with aortic regurgitation, 4 patients with hypertensive heart failure and 4 patients with congenital heart disease.

Experimental animals were 15 dogs which had to undergo procedures of tricuspidal valvotomy and pulmonary artery stenosis.

A catheter was introduced into the pulmonary artery, right heart, vena cava inferior and hepatic vein, and Cournaud's needle was inserted into brachial or femoral artery for collection of the arterial blood sample. The pressures were recorded by capacitance manometer, the point of zero reference being 5 cm posterior to the fourth left costochondral junction. The oxygen content of the blood samples was determined by the direct Fick method, the hepatic blood flow was estimated by the colloidal radiogold method of Vetter et al.

We have produced experimentally congestive heart failure in dogs by modification of Veith & Thrower's technique*. In the first stage, the valvulotome was inserted into the ventricle through the right auricular appendage, and divided the chordae tendineae of the tricuspid valve. In the second stage, two or three weeks after the first operation, pulmonary artery stenosis was created. Pulmonary artery was excised to occlude the artery partially by reducing its diameter 50 to 60 per cent. Fifteen dogs have been operated on successfully. Frank congestive failure with marked ascites has been produced in 10. One of them (No, 4) has had about 6,000 cc of ascites.

RESULTS

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84 Japanese Circulation Journal Vol. 28, February 1964
As compared to normal subjects, relatively higher pressure of venous systems were obtained in patients with cardiac diseases and experimental dogs. In 19 patients with cardiac disease, the pressure of right auricle ranged from 1.0 to 16.0 mmHg with a mean of 5.7, the vena cava ranged from 1.0 to 20.0 mmHg with a mean of 5.7, the free hepatic vein ranged from 1.0 to 19.0 mmHg with a mean of 7.8 and the wedged hepatic vein ranged from 2.0 to 25.0 mmHg with a mean of 9.4. In 15 experimental dogs, the mean pressure of right auricle was 6.9 mm Hg, free hepatic vein was 10.8 mmHg. Demling and co-worker\(^5\) have described a method of estimating portal venous pressure by rectal capillary bloodless method. The pressure required for the occlusion of capillaries in the upper rectal mucosa provides a good index of portal vein pressure. In our data, the rectal capillary pressures were for the controls 120 ± 15 mmHg, and for the 15 cardiaics ranging from 115 to 320 mmHg, with a mean of 170.5 mmHg.

Cardiac indices (cardiac output in liters per min. per sq. M. of body surface) in the group with heart disease and the experimental dogs showed subnormal values. The means of these determinations were for the 17 cardiaics 2.7 ml., and for the 12 dogs 2.6 ml.

The hepatic blood flow for the 11 patients with heart disease ranged from 309 to 880 ml. per min. per sq. M. of body surface; the controls gave values of from 730 to 1160 ml. per min. per sq. M. The average values for the cardiaics are 459 ml. and for the controls 875 ml.

In the 17th experimental dogs, the hepatic blood flows ranged from 356 to 943 ml. per min.

Fig. 1. The hepatic blood flow in the patients with heart disease (A) and the experimental dogs (B).

The oxygen contents of arterial blood, mixed venous blood and hepatic vein blood in most of cases with cardiac failure and of experimental dogs with ascites were reduced. However, most of cases in cardiaics and in experimental dogs, arterial-mixed venous oxygen differences were elevated, the values ranging for the cardiaics from 3.5 to 11.8 volumes per cent with a mean of 6.1, for the dogs from 1.5 to 11.0 volumes per cent with a mean of 4.4. Arterial-hepatic venous oxygen differences corresponded, the cardiaics showing elevated values ranging from 3.3 to 14.0 volumes per cent for a mean of 7.1, and the experimental dogs ranging from 2.0 to 11.7 volumes per cent for a mean of 5.6.

The splanchnic oxygen consumption (hepatic blood flow × hepatic arterio-venous oxygen difference) in the patients with cardiac disease ranged from 19 to 56 ml. per min. per sq. M. with a mean of 33.4 ml. and in the experimental dogs ranged from 12.6 to 41.1 ml. per min. per sq. M. with a mean of 24.8 ml. These values of the experimental subjects were relatively lower as compared to normal values (Fig. 2).

![Fig. 2](image)

Fig. 2. The splanchnic oxygen consumption in the patients with heart disease (A) and the experimental dogs (B).

The plasma proteins tend to be lowered in congestive heart failure. The means of these determinations were for the 27 patients with cardiaics 6.6 gr. per 100 ml., and for the 15 dogs 5.6 gr. per 100 ml.

**DISCUSSION**

The pressures of right heart and vena cava in patients with cardiac disease and in experimental dogs are elevated. Especially, the eleva-
tion of hepatic vein pressure are remarkable, and there are only a slight gradient between the free and wedged hepatic vein pressures. This reflects the elevation of pressures in the right side of the heart and vena cava inferior.

Furthermore, the data of the rectal capillary pressure, which required for the occlusion of capillaries in the upper rectal mucosa provides a good index of portal vein pressure, is remarkably elevated in the patients with congestive heart failure.

Hepatic blood flow is decreased in cardiac failure and in the experimental dogs with ascites. When the values for hepatic blood flow and cardiac index in each patient and experimental dog are correlated, it is found that the hepatic blood flow is reduced in proportion to the reduction in the cardiac index.

Myers described that in both the control group and in the series with heart failure, the hepatic blood flow represented a fairly constant percentage of the cardiac output. But, our experimental subjects, in relationship with the hepatic blood flow and cardiac index, indicate that the hepatic flow is more remarkably reduced (Fig. 3).

It has been considered that the decrease of hepatic blood flow depends not only on the decrease of cardiac output, but also on the elevation of venous pressure and resistance in the liver itself. In the relationship of hepatic blood flow to atrial and hepatic venous pressure, there is correlation between the level of the flow and corresponding right atrial or hepatic venous pressures. Particularly, the experimental dogs with right heart failure and ascites do show reduced hepatic blood flow in proportion to elevated pressures of venous system (Fig. 4).

Fig. 3. The relationship of hepatic blood flow to cardiac index in the patients with heart disease (A) and the experimental dogs (B).

Fig. 4. The relationship of hepatic blood flow and hepatic venous pressure in the patients with heart disease (A) and the experimental dogs (B).

For example, three dogs (Number 4, 14, 15), which were suffering from marked congestive right heart failure with ascites, did show reduced hepatic blood flows in conjunction with

*Japanese Circulation Journal* Vol. 28, February 1964
HEPATIC CIRCULATION IN CONGESTIVE HEART FAILURE

elevated venous pressures, postmortem histological data was obtained after performing the venous catheterization. The histological changes in the liver of dog number 14, autopsy was performed at 4 weeks after operations of tricuspid valvotomy and pulmonary artery stenosis, and dog number 15, at 6 weeks after operations, both were found that the central vein was dilated, and there was hemorrhage from the sinusoid with focal necrosis of the liver cells, following by centrlobular reticulum proliferation (Fig. 5). Dog number 4, at 3 months after operations,

had the so-called cardiac cirrhosis in the liver. The protein concentrations of ascitic fluid of these dogs ranged from 3.5 to 4.8 gr per 100 ml.

In animals, experimental obstruction of the venous return from the liver is a common way of producing ascites, and which has a particularly high venous pressure and associated centrlobular liver cell damage.

It has been found that the ascites developing under these condition was attributed to increased production of hepatic lymph, and which showed high protein content. The ascitic fluid of our dogs with congestive right heart failure also has a high protein content and analogous to that observed with the experimental hepatic venous or vena cava obstruction.

Oxygen contents of arterial blood and venous blood in various region were decreased in patients with congestive heart failure and dogs with ascites.

The liver is particularly sensitive to oxygen lack. The liver cell at the center of the lobule receive blood at a lower oxygen tension than at the periphery. Anoxia, then, is known to be the cause of the centrlobular degeneration and dilatation of sinusoid.

Catheterization studies in our subjects have shown that the oxygen supply to the liver was decreased with diminishing cardiac output and hepatic blood flow.

In spite of the arterial oxygen saturation in most cases of congestive heart failure are slightly reduced, but the arterial-hepatic venous oxygen difference allows the body to maintain a normal splanchnic oxygen consumption.

In general, it has been recognized that the individuals in heart failure with a reduced cardiac output, maintains a normal body oxygen consumption by an increased arterial-mixed venous oxygen difference.

We obtained the similar findings on the hepatic circulation with heart failure on moderate number of cases (Fig. 6). But, in the patients with severe congestive heart failure and experi-

Fig. 5. Dog. No. 4. The data of catheterization studies before and after the operations of tricuspid valvotomy and pulmonary artery stenosis, and postmortem pathological findings.

Japanese Circulation Journal Vol. 28, February 1964
mental dogs with ascites, the splanchnic oxygen consumption was clearly decreased (Fig. 2).

The plasma proteins tend to be lowered in our subjects with congestive heart failure. Felder and coworkers found evidence of malnutrition paralleled to the duration and severity of the cardiac disease. This low plasma protein values may be occur in the patients having no appetite, being on a restricted diet, and with defective hepatic synthesis of protein. They also occur in most oedematous patients, in whom protein, particularly albumin, is lost into oedema and ascites. The malnutrition may also be a contributory factor in the production of the hepatic lesion.

CONCLUSION

In congestive heart failure, the influence of alterations of the systemic circulation on the liver was considerable, as following mechanism.

1) The hepatic blood flow in cardiac failure was moderately reduced in proportion to the reduction in total cardiac output. But, the former was more reduced than the latter particularly in the dogs with ascites.

2) The hepatic venous pressure was elevated in heart failure, reflecting to the rise in pressure in the vena cava, and this might conduce to the centrilobular necrosis and fibrosis. This histological changes in the liver leading also to hepatic blood flow was reduced due to increased hepatic resistance itself.

3) Ascitic fluid of the dogs with severe heart failure had a high protein content, and this phenomena was probably similar to that observed with the experimental hepatic venous obstruction.

4) The reduction in hepatic blood flow was compensated by an increase in arterial-hepatic venous oxygen difference which provided a normal splanchnic oxygen consumption. But, in the patients with severe congestive heart failure and dogs with ascites, splanchnic oxygen consumption was decreased.

5) The oxygen supply to the liver was decreased with diminishing cardiac output and hepatic blood flow. The anoxia may play a role in the production of hepatic lesion.

6) The malnutrition in congestive heart failure may be as have a similar importance as anoxia and hepatic venous hypertension.

REFERENCES


2. Hepatic Circulation and Ascites in Congestive Heart Failure+

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Liver cells are supplied their blood from two blood vessels i.e. hepatic artery and portal vein, and these two vessel systems are supposed to have each contribution to the liver cells; portal vein is thought to contribute more in supplying nutrition and hepatic artery more in supplying oxygen. Consequently I want to discuss the following problems in this treaty: What is the relationship between the blood flow to the hepatic artery and to the portal vein in

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Japanese Circulation Journal Vol. 28, February 1964